Rewinding Power Transformers for 13.8V Power Supplies

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Increasingly, radio equipment is designed to run from a nominal 12 or 13.8 Vdc supply, and may demand perhaps 10, 20 or more amps dc on transmit. Because many amateurs like to build (and save money), various journals have published plans for 240 Vac : 13.8 Vdc power supplies, and these have entered the mainstream of popular projects (Refs 1-7). We now have the choice of building a conventional (50 Hz-transformer type), or a switch-mode supply.

Switchers are rapidly replacing conventional supplies in new domestic and industrial applications, mainly because they are cheaper, more efficient, cooler, lighter and smaller than an equivalent 50 Hz-transformer device. However, if not properly designed, screened and filtered, switchers can also emit a lot more electrical noise. In amateur radio work, to have a 20 or 50 or 100 kHz, 500 W, square-wave power-oscillator running right there in the shack (or even in the same house) can have disastrous effects on weak-signal reception. So, in our case, it may be that a conventional power supply is more appropriate. Moreover, a conventional supply can generally be more easily built by the amateur using parts gathered from here and there.

Having chosen to make a conventional supply, the builder soon finds that a new power transformer is a very costly and/or hard-to-get item. Adequately power-rated transformers may be rescued from defunct TV sets and other appliances. But their secondary winding voltages are nearly always unsatisfactory. Fortunately, in most instances, it is quite possible for a handy person to rewind a transformer secondary to requirements.

Transformer size, and hence power (VA) rating is dictated by the dc load. For example, a transceiver which requires a supply of 13.8 Vdc (14 V in round figures) at up to 10 A is a full load of 140 W. To regulate properly, the popular LM723/2N3055 pattern generally requires a full-load transformer secondary winding r.m.s. voltage of about 1.4 times the dc output voltage; 1.4 X 14 = 19.6 rounded to 20 Vac. In practice, due to the reservoir capacitor, about 10 % more alternating current than dc load current will flow from the secondary. Therefore, at maximum output current demand the secondary load is 20 (volts) X 11 (amps) = 220 W (strictly VA). Power dissipated in the series pass transistor(s), diodes and other resistances being 220 - 140 = 80 W. So in this example we require a transformer rating of at least 220 W, and preferably a bit more for safety margin (Refs 1and 8).

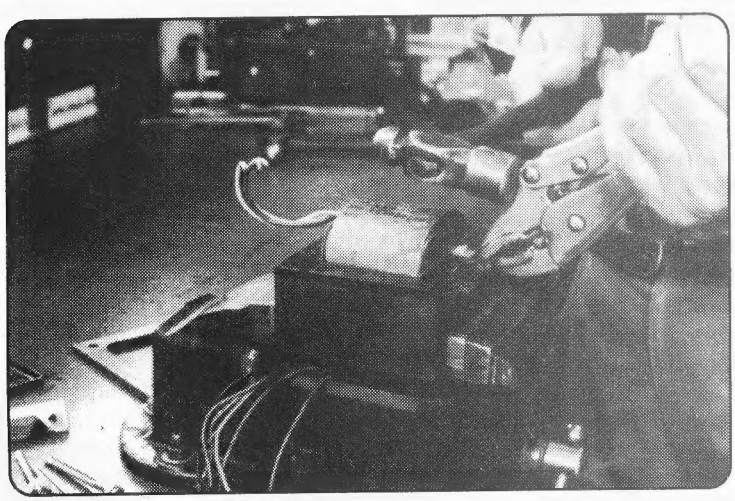

Photo 1. Extracting the first lamination

VA power rating in W may be calculated W = (5.58 X A) squared, where A is the core cross-sectional area in square inches, or W = (0.00865 X A) squared where A is in square mm (see Fig. 1). In this example, the core is 1.94" X 1.38" = 223 W- probably just large enough for an 8 A power supply (Refs. 10, 11). If you have a choice of types, select one which has a bobbin/former with end cheeks (like Fig. 1), as these are generally much easier to work with. Those with a separate section ("double-bobbin") for primary and secondary are even better. Transformers which are covered with a thick layer of shellac or varnish, or have a 'C' type core are usually too difficult to take apart, and are not suited to amateur rework.

It would be prudent to check the serviceability of the transformer before any work is done on it. As a preliminary test, use your multimeter on ohms to measure the primary winding resistance- should read about 3 ohms for a 500 VA, to about 6 ohms for a 200 VA. Reverse the meter connections- observe a more sluggish needle deflection to settle at previous reading (due to the inductance of a good primary winding and residual magnetism in the core). On highest ohms range, test for open circuit between core and primary. Using a mains cord and plug, connect a 60 or 100 W 240 V lamp in series with the primary winding (Ref. 8). Tape over the connections to prevent accidental contact (and interpose a 1:1 mains isolation transformer if available). Ensure that no external shorts exist. Keep hands away from the set-up. Apply mains power. For a good transformer, the lamp should only glow dull red to

orange, indicating just a small 'magnetising' current (typically about 100 mA). If the lamp glows bright, there is probably some fault, perhaps a 'shorted turn', either in the primary or secondary. The core should only be slightly warm after some hours of operation.

Disconnect the lamp and power the primary direct from mains. If the primary has taps, (often 210, 220, 230, 240, 250 V), select the correct tap for your local supply voltage. Measure and record the secondary winding voltages- take great care, one winding may well be 100 V or more. Often, one of the windings will be low voltage, perhaps 6 V or so. Take particular note of this winding.

Remove the two or four retaining bolts and mounting hardware, noting the position of any fibre/plastic washers. Some transformers have a copper slug band fitted (to reduce flux leakage)- we won't need that- cut off with tin-snips. The core will be comprised of interleaved E and I shaped laminations. Now we come to the tricky part- getting that first lamination out of the core. Fix the core in your vice. Using a reasonably sharp knife, insert the blade (may need a tap with small hammer) under the first I lamination, which should snap away. Run the knife blade around under the E lamination and free it as much as possible. Now lever up the E where it enters the bobbin sufficient for a pair of vice-grip pliers to be applied. Using a small hammer, strike the pliers as depicted in Photo 1, and carefully drive out the lamination (which may be deformed beyond repair - never mind). Thereafter, it should be possible to remove the alternate E's and I's without damaging them.

With the core extracted from the bobbin, cut off the outer layer of insulation to expose the winding(s), then unwind each layer. When the known voltage winding (e.g. 6 V) is removed, carefully count and record the number of turns. A HT winding will take a bit of time to strip, and there may be a temptation to get stuck into it with a hacksaw. Don't do it, as there is the danger of going too far and cutting the primary. The primary is the winding closest to the core, so leave the insulating covering for that winding intact.

Most transformers of my experience have a volts/turn of between 0.3 and 0.5. The one in this example had 15 turns for the 6 V winding; 6 divided by 15 = 0.4 volts /turn. Another way of expressing it is turns/volt, which in this instance is 15 divided by 6 = 2.5 turns/volt. That is, for every 2.5 turns around the bobbin we get one volt. For a 20 V winding, I will therefore need to wind on 2.5 X 20 = 50 turns.

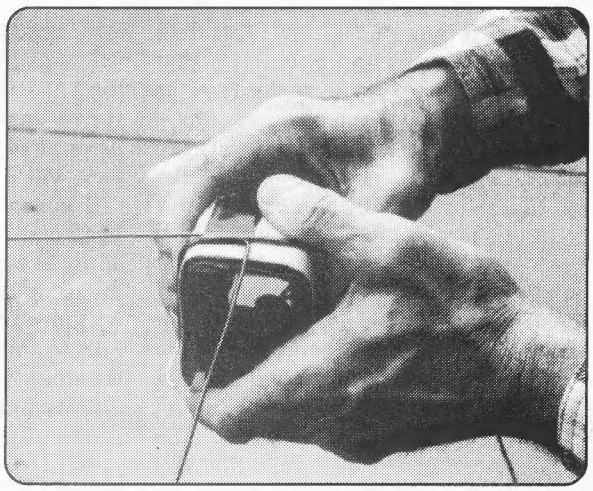

Photo 2. Winding the new secondary

Ordinary copper wire tables sometimes give current carrying capacity- but these are generally for 'open' applications. In a transformer, the wire is closely packed, and so the copper-loss heating effect is greatly increased. The generally accepted figure is between 1500 and 1800 A per sq. inch cross-section of copper (Refs. 8, 10), which results in the figures given in Table 1.

Current A	B&S	S.W.G.	mm	inch
20	8	10	3.25	.128
15	10	12	2.64	.104
10	12	14	2.03	.080
5	14	16	1.63	.064
3	16	18	1.22	.048

Table 1

Select the appropriate wire gauge for your application. If in doubt, err on the larger size (but see next para.). Enamelled copper wire of the kind used in electric motors, alternators and so on is quite well-suited to transformer work. Some auto-electricians, armature/ electric motor re-winders and transformer makers/repairers will sell wire of various gauges. In addition, Melbournians have O.H. O'Brien Pty Ltd (ph 039699 8122), who are magnet-wire wholesalers. Electronic World (ph 039723 3860) can also supply some popular sizes on request.

A 20 V winding can usually be fitted in the space vacated by the old winding(s). However, it is a good plan to check; insert an E lamination into the bobbin and measure the winding window available, then, knowing the wire gauge, work out the total cross-sectional area required by your winding. Remember that in practice it will always be a little larger, by perhaps 10 %, than the area calculated. Also, for a plain bobbin/ former without cheeks, it is not possible to bring the winding right up to the former's edge without the wire slipping over the side.

Estimate the length of wire required (probably about 12 m for a 20 V), then un-spool that amount. Do not scratch or nick the enamel. Fix one end firmly (perhaps by clamping the spool in your vice), then grip the free end with bullnose pliers and give the wire just sufficient pull to straighten out any small wrinkles. To begin the winding, place a 90 degree bend in the wire, leaving sufficient for terminating. To keep the winding start in place (for a plain bobbin- without cheeks), wrap a flag of insulating tape around the wire

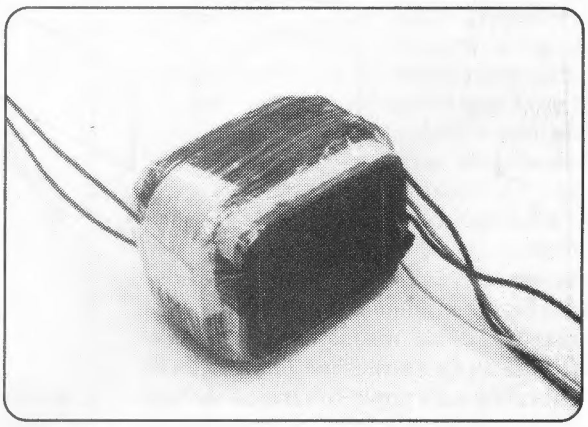

Photo 3. Winding complete

at the beginning of the first turn, then lay the flag upon the bobbin so that successive turns pass over the tape, as shown in Photo 2. Have tape and cutters in your pocket. Whilst maintaining tension on the wire, walk towards the spool, winding the turns on and counting as you go. With the winding done, perhaps a helper could hold the bobbin as the wire is cut (maintain that tension) leaving sufficient length for terminating, then put a bend in the wire similar to the start. Apply two or three layers of tape over the finished winding (Photo 3). Ordinary wide sticking tape (in my experience) stands up quite well in transformer work, although fibreglass tape is best if available.

Reassemble the core by interleaving the E's and I's. Take note of the colour of the laminations; some rely on an oxide layer for insulation (between laminations), and may be light on one side, darker on the other. They must therefore be replaced with same colour facing up each time. Fully lacquered laminations are not 'polarized'. When the core is nearly complete, it will be possible to knock the core into proper shape upon your bench-top. The last one or two laminations will probably need to be carefully tapped home. A squeeze in the vice sometimes helps in getting the stack to compress down sufficient to admit the last lamination. Don't worry about that mangled E.

Replace the external hardware and the two or four fixing bolts, being careful to refit any fibre/plastic washers correctly. Power-up the transformer with series lamp as described above, and check that the primary magnetising current is still a low value (dim red-orange glow). All being well, apply full mains voltage and carefully measure the secondary voltage, which should be pretty close to your calculated value. Should some error occur- voltage a little low or high, it is possible to 'fudge' a bit by using (say) the 230 or 250 V primary tap if available. However, we should be very wary of using anything lower than the 230 V tap for a 240 V mains supply.

If some high-wattage wire-wound resistors, or a rheostat are available, apply a suitably rated dummy load to the secondary to test that the transformer will indeed deliver the power required. For example, a nominal 20 V, 8 A winding, when loaded with 2.5 ohms may (typically) fall from 20.5 V no-load to 19.5 V full-load.

References and Further Reading

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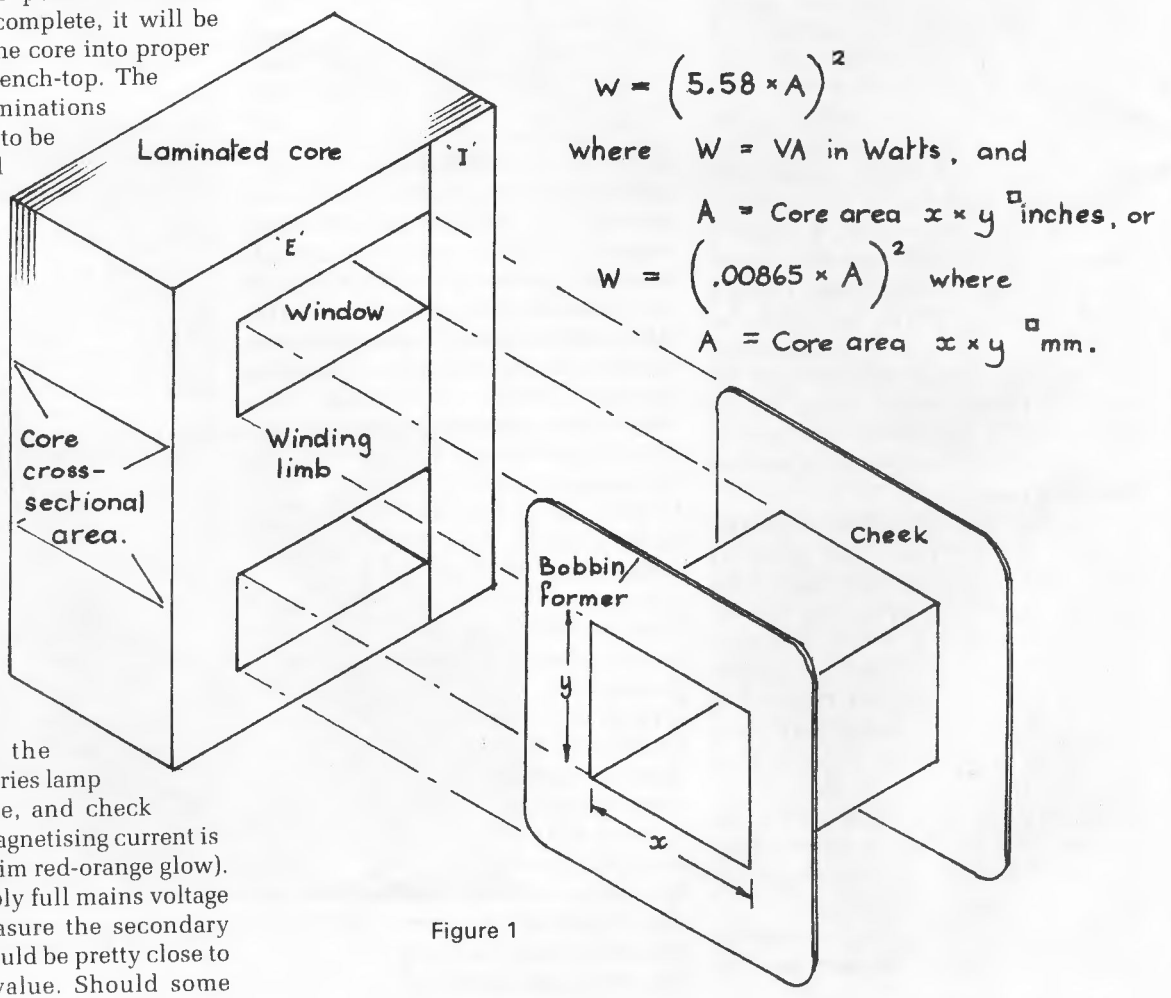

Figure 1